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CFD ANALYSIS OF FLOW PAST A SQUARE CYLINDER AND A SPLITTER PLATE ARRANGEMENT AT LOW REYNOLDS NUMBER

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Abstract
Aerodynamic characteristics of a square cylinder with a splitter plate arrangement at a low Reynolds number is studied in the present paper. The flow analysis is done using ICEM CFD and FLUENT and its validation is done. The study of flow past square cylindrical obstacle has fascinated researchers for a long time. Cylindrical structures submerged in wind, tides or currents are some of the examples for the mentioned flow. The case with a splitter plate is also an area of interest.As the distance between the cylinder and plate varies, the flow patterns differs. The flow pattern also depends up on Reynolds number. This paper presents the results of two-dimensional flows around a square cylinder and a splitter plate at a Reynolds number of 100 when splitter plate is kept at varying distances from the cylinder.

Introduction
The flow past a cylinder is one of the most studied phenomenon of aerodynamics because of its simple geometry as well as the logical structure of its vortices. The studies were led on one hand by academic interests and on the other are relevant to many engineering applications like cross-flow heat exchangers, automobiles, architectural structures, such as buildings, bridge decks, and monuments, etc.
A cylindrical body induces various instantaneous unsteady effects like flow-separation, reattachment bubble, shear-layer instability, vortex shedding when flow pasts over it, resulting in a large value of drag coefficient. In many engineering applications, it is desirable to minimize this Drag coefficient, CD.
Bluff body cross-sections that are regularly used in applications are rectangular and circular. It is well- established that the flow details depend on the average incoming velocity and the characteristic transverse dimension of the body. The incoming velocity is defined on the basis of the Reynolds number.
Low Reynolds number flow has been the subject of investigation in recent years. Pavan and Gera [1] performed CFD analysis for unsteady, incompressible 2D flow around a square cylinder at zero angle of incidence for Re ranging from 50 to 250. They predicted the influence of Reynolds number on quantities such as Strouhal number and lift, drag, and base suction coefficients.
In this paper, we focus on the flow past a square cylinder and a splitter plate arrangement at a Reynolds number of 100 with varying distances between the control plate and cylinder. The experimental data obtained from [2] is used for validation of CFD results obtained using ANSYS FLUENT.

Geometry
The geometry of the problem is depicted below. A square cylinder and a splitter plate at a distance H is kept and along it a fluid (air) is passed at a velocity corresponding to the Reynolds number. The flow pattern across the arrangement is studied when the splitter plate is kept at variying distances and effect of splitter plate in the arrangement is studied. Here H is the distance between cylinder and plate and D is the diameter of the square cylinder. In the problem we consider the cylinder dia as 10mm and the values of H is varied. Ie the H/D ratio is taken as 3.75, 4, 4.25, 4.5 and 5 and the geometries are plotted.

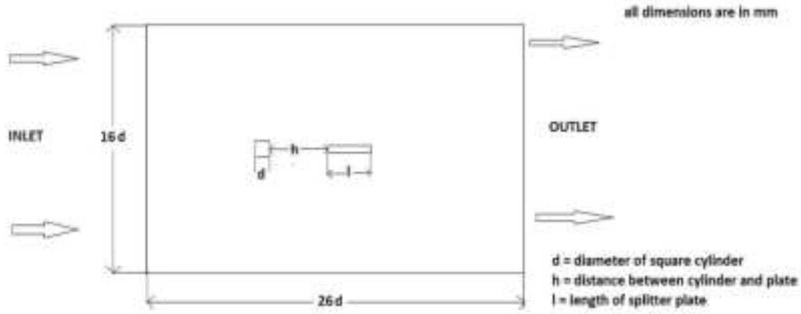

Figure 1 geometry

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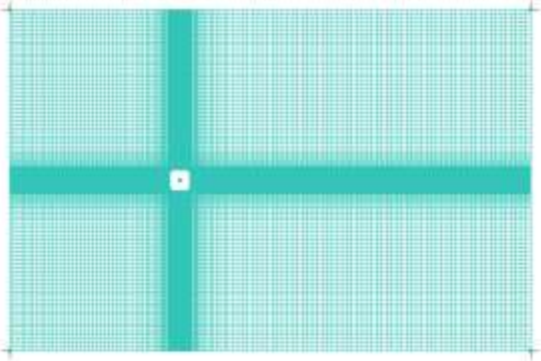
The objective was to study the effect of a splitter plate at varying distances from the cylinder and to observe the vortex formation, variation of coefficient of pressure and velocity variations due to the splitter plate at different distances.

Validation & mesh generation

The meshed geometry used for the validation purpose was of the case of an isolated square cylinder. The mesh is shown below.



Grid independence test

The grid independent test was conducted by using Re=100 for square cylinder. This was done in order to see the effect of variation in grid over the valves of total drag and total lift co-efficient and the values were compared with Pavan and Gera [1]
The mesh was generated in a fine, finer and coarser way and the results obtained shows that the variation of mesh counts does not affect the coefficients of drag or lift. Hence we choose a moderately meshed grid for our study.
Modified model
The geometry of our problem was modelled and meshed in ICEM-CFD. Due to the simple nature of geometry, hexahedral mesh was used. A 2D analysis was done for understanding the of flow physics especially at lower Reynolds numbers. A finer mesh was used near to the wall to capture the boundary layer flow accurately. A coarser mesh was used to mesh the remaining.

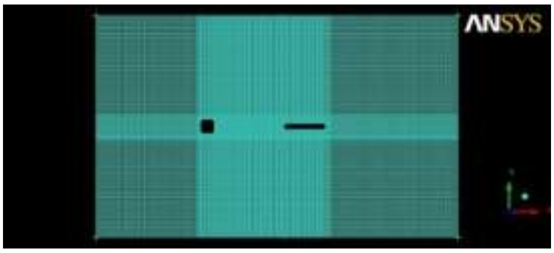


Figure 2 mesh

Methodology

The flow simulations were done using the ANSYS FLUENT solver. Air was taken as the operating fluid, and its properties were determined from approximating formulae based on literature. Initially, the simulations were done considering the flow as steady to determine the friction factor. The simulation of vortex formation, cp and velocity variations in the cavities was done by simulating unsteady flow conditions.

Boundary conditions

The fluid was taken as air. Inlet was specified as velocity inlet and outlet as outflow. No slip conditions were provided on the cylinder wall, splitter plate, top and bottom wall

Measurement of data

The velocity of flow was determined using the formula, $R_e = \frac{\rho v d}{\mu}$, where, ρ is the density of air 1.225, v is the unknown velocity, d is the diameter 10mm and μ is the viscosity 1.7894 e^{-5}

Results & discussion

The plots obtained for the Cd and Cl for the 5 cases, the velocity magnitude, Cp and the vorticity magnitudes are given below. The splitter plates were kept at 5 distances corresponding to the $\frac{H}{D}$ ratios as 3.75, 4, 4.25, 4.5 and 5. The rms values of coefficient of drag and lift for all the cases are also tabulated and is plotted as a graph.

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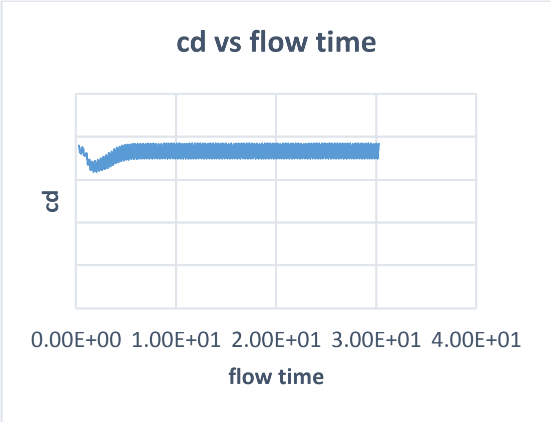

Figure 3 cd vs flow time (4)

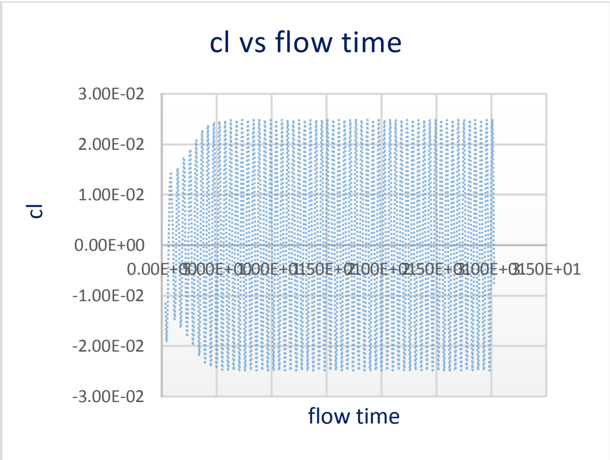

Figure 4 cl vs flow time (4)

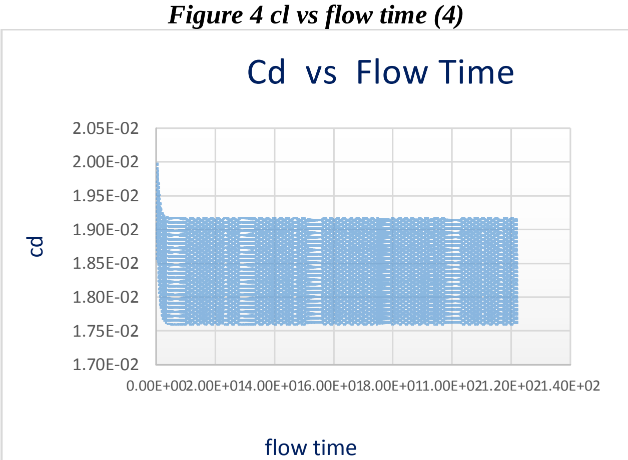

Figure 5 cd vs flow time (4.25)

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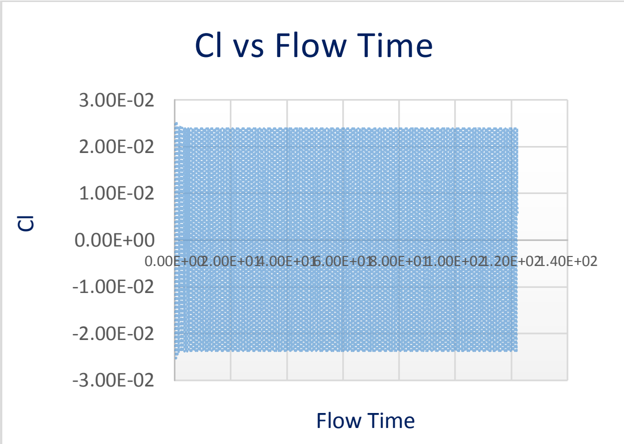

Figure 6 cl vs flow time (4.25)

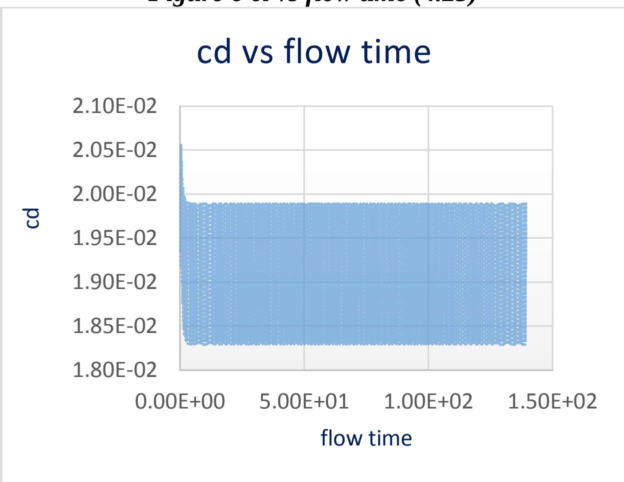

Figure 7 cd vs flow time (4.5)

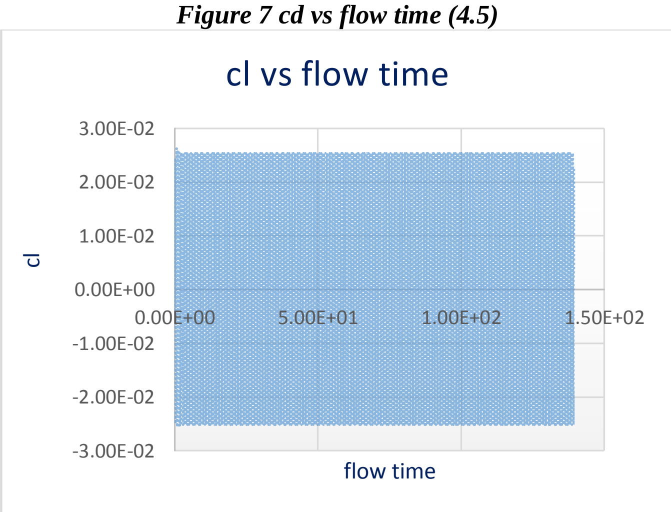

Figure 8 cl vs flow time (4.5)

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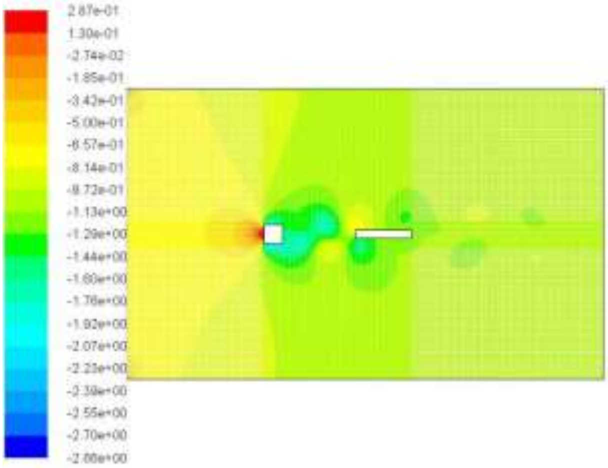

Figure 9 coefficient of pressure (4)

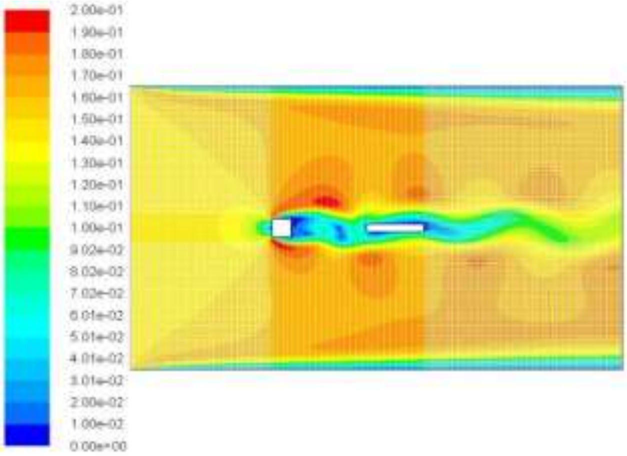

Figure 10 velocity magnitude (4)

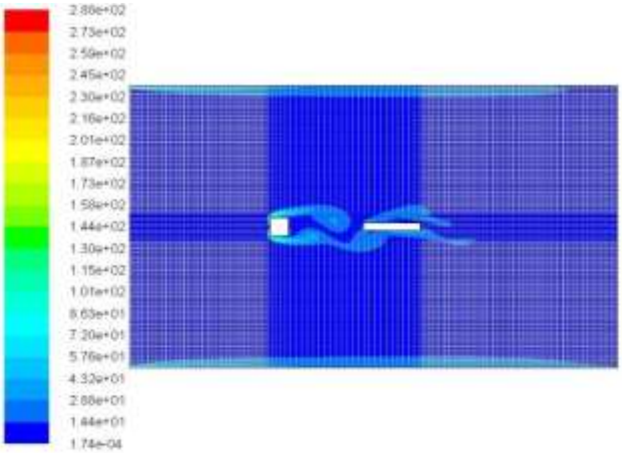

Figure 11 vorticity magnitude (4)

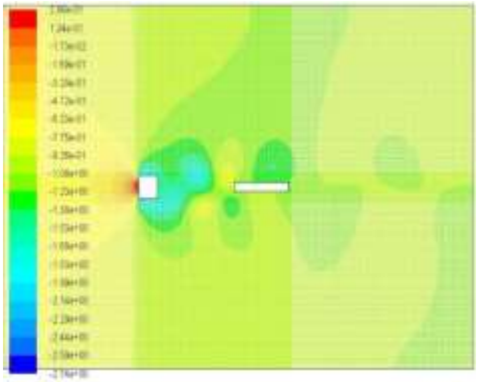

Figure12 coefficient of pressure (4.25)

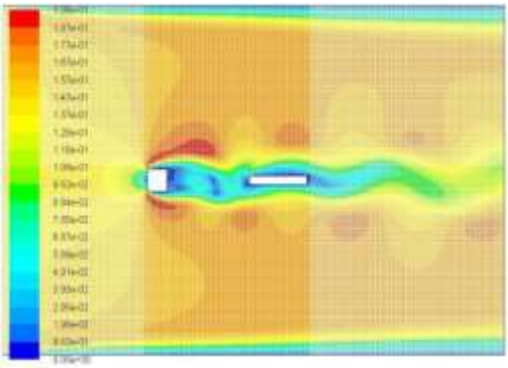

Figure 13 velocity magnitude (4.25)

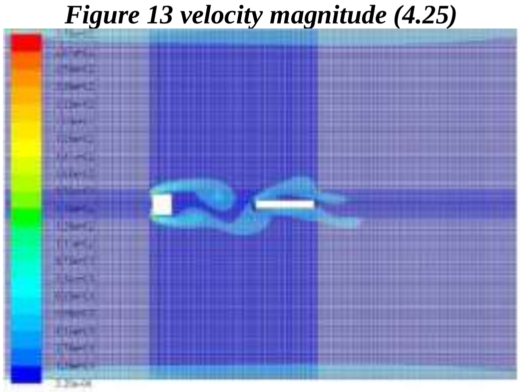

Figure 14 vorticity magnitude (4.25)

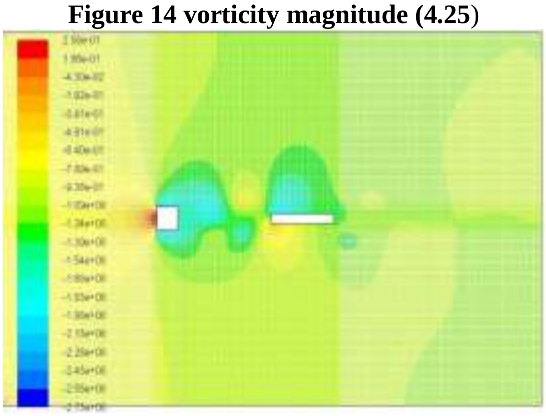

Figure 15 coefficient of pressure (4.5)

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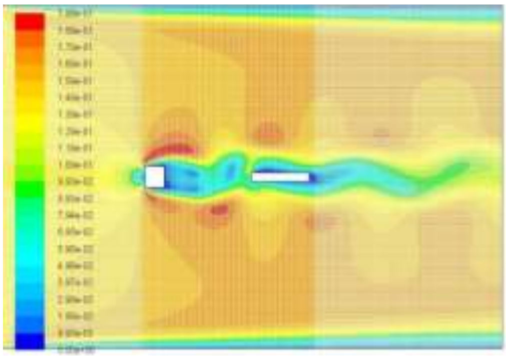


Figure 16 velocity magnitude (4.5)

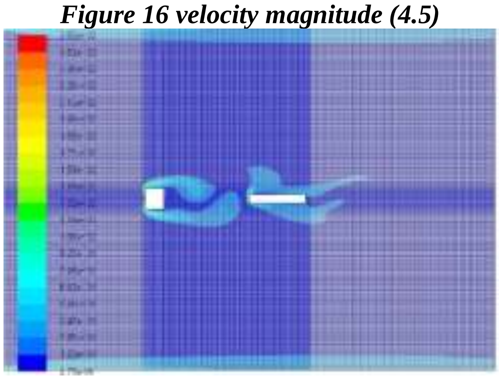
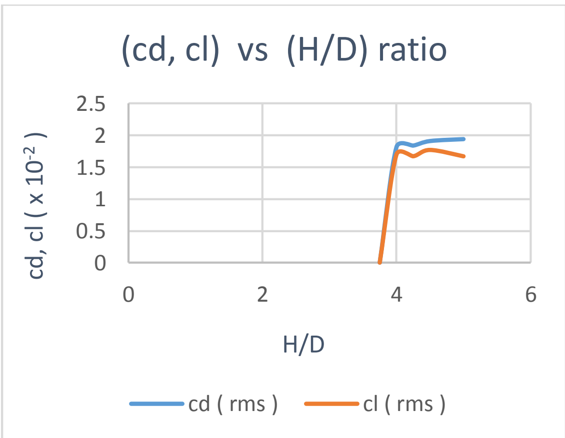


Figure 17 vorticity magnitude (4.5)

Table 2. Variation of Cl,Cd with h/d ratio.

h/d	cd (rms) x 10^{-2}	Cl (rms) x10^{-2}
3.75	0.0047	0.0053
4	1.8167	1.7012
4.25	1.8401	1.6736
4.5	1.9111	1.7724
5	1.941	1.6723



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Conclusion

From the plots we can see that till the splitter plate is at 37.5mm from the cylinder, it has no effect on the flow. But on increasing the ratio further we see variations in cd and cl values. This means the splitter plate causes disturbances to the flow pattern. This concludes that for a square cylinder and splitter plate arrangement at a low Reynolds number of 100, the minimum distance between the cylinder and plate lies between 37.5mm and 40 mm. ie the $\frac{H}{D}$ ratio should be between 3.75 and 4.

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